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# Eye-direction detection: A dissociation between geometric and joint attention skills in autism

**Susan Leekam**[*]
*Department of Psychology, University of Kent, Canterbury, Kent CT2 7LZ, UK*

**Simon Baron-Cohen**
*Department of Experimental Psychology and Psychiatry, University of Cambridge*

**Dave Perrett** and **Maarten Milders**
*Psychological Laboratory, University of St Andrews*

**Sarah Brown**
*Department of Psychology, University of Kent*

This study examined differences between children with autism and control children in the ability to follow another person's direction of gaze. In Expt 1, children with autism, Down syndrome and normally developing children were given two tasks. The *gaze monitoring task* (GMT) measured the child's spontaneous tendency to follow gaze direction in response to another person's change of head and eye movement. The *visual perspective taking task* (VPT) measured the child's ability to compute and report what the other person was looking at, when instructed to do so. Results showed that the majority of Down syndrome and normal children passed both tasks. In contrast, children with autism failed the GMT. This failure could not have been due to a lack of the relevant geometric skill, as they passed the VPT. This geometric skill was examined further in Expt 2, using a fine discrimination task which tested children's ability to discriminate degrees of change in the orientation of gaze. Children with autism were well within their developmental age level on this task. These results indicate a dissociation between (impaired) spontaneous monitoring and (intact) geometric analysis of gaze–direction.

Joint attention behaviours include a range of behaviours effective for gaining, following and sharing the attention of another. Joint *visual* attention behaviours include following another's gaze, pointing out and showing objects to others. These behaviours appear in

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[*] Requests for reprints.

normal development from about 10–14 months (Butterworth, 1991; Corkum & Moore, 1995; Morisette, Ricard & Decarie, 1995) irrespective of culture (Bruner, 1983).

Whilst the ability to engage in joint visual attention is an early accomplishment in normal development, the evidence for this ability in children with autism is somewhat contradictory. On the one hand, there is evidence that children with autism can monitor another's gaze direction. This is shown by their performance on *visual perspective taking* tasks in which a person turns their head or eyes towards an array of objects and the child is asked to report what the person is looking at (Baron-Cohen, 1989, 1991; Dawson & Fernald, 1987; Hobson, 1984; Tan & Harris, 1991). Children with mental ages above 3 to 4 years of age perform well on these 'geometric' tasks. In contrast to this ability, however, children with autism do not spontaneously monitor gaze in joint visual attention. This is shown by their performance on a *gaze monitoring* task which tests spontaneous responses to a person's change of head and eye-movement (Scaife & Bruner, 1975). When this task is given to children together with other joint attention measures, children with autism show a response deficit (Landry & Loveland, 1988; Loveland & Landry, 1986).

This evidence indicates that in autism there might be a dissociation between joint attention and geometric ability in eye-direction detection. Previous studies, however, have always tested participants on *either* the visual perspective taking task (VPT) *or* the gaze monitoring task (GMT) and have not examined the relationship between these abilities. In addition, the GMT has always been combined with other joint attention skills (e.g. showing, requesting gestures etc.) rather than being tested independently. In Expt 1 we therefore tested for a dissociation between visual perspective taking and spontaneous gaze monitoring abilities within the *same* group of participants.

One factor we were interested in was the effect of age and verbal ability level. Visual perspective taking ability is found in normal development from the age of 3 years (Lempers, Flavell & Flavell, 1977). Studies using the VPT in autism have been carried out with individuals who have a verbal mental age (VMA) above 3 years. The autistic participants in Baron-Cohen's (1989) study, for example, had a mean VMA of 5.5 years. In contrast, studies using the spontaneous gaze monitoring task (GMT) have been carried out with much lower functioning participants. One question, therefore, is whether children with a higher verbal mental age who monitor gaze in the VPT also monitor gaze spontaneously in the GMT.

The link between verbal ability and joint attention has been explored in studies by Loveland & Landry (1986) and Landry & Loveland (1988) with mixed results. Loveland & Landry (1986) found that joint attention behaviours were not related to non-verbal MA or to mean length of utterance (MLU), whilst Landry & Loveland (1988) found attention directing gestures were positively related to language level. One difficulty with assessing the link between verbal ability and joint attention as assessed in these studies is that joint attention measures traditionally include a range of behaviours, e.g. requests, showing, touching, pointing, use of pronouns etc., and they include both attention directing behaviours by the child and responses to another's attention. By isolating one joint attention behaviour, the response to another's head and eye movement, it is possible to establish whether this behaviour is specifically related to age and verbal ability for children with autism. Since the mean MLU of children in both the Loveland & Landry studies was only 1.95 years, it is not clear if joint attention would have been found in children who have more language than this. In Expt 1 we therefore investigated performance on the GMT and VPT in children with verbal MAs above and below 4 years old.

This study also gave us the opportunity to investigate spontaneous gaze monitoring in two groups which had not previously been tested on the GMT: children with Down syndrome and a group of older normal children aged 5 years. Most normal infants spontaneously monitor gaze by the age of 14 months and we predicted that the majority of older children and MA-matched Down children would perform similarly. There are several aspects that are unknown for children with delayed development, however. One concerns the child's ability to follow a person's gaze to a location behind the child. For young normally developing infants, monitoring gaze to a location behind creates problems, even for 18-month-olds who can monitor gaze to the left and right (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991). A similar phenomenon of failure to look behind has also been found in non-social development in the manual search skills of infants (Landau & Spelke, 1988). It is not known if this problem persists into later childhood or if it is a feature of gaze monitoring in the developmentally delayed child. Another aspect concerns consistency of responses. Whilst the infancy studies show that the majority of infants from 10–12 months will monitor gaze, no studies as yet show an upper age limit with 100 per cent consistent response level. When analysing correct response on trials within the visual field, Butterworth & Cochran (1980) found correct responding on 74 per cent of trials by 12-month-olds and 87 per cent of trials by 18-month-olds. Other studies, using different scoring procedures (Scaife & Bruner, 1975; Corkum & Moore, in press) indicate that, while infants do respond by monitoring gaze, they do not do this on every trial. It is not known whether the reliability of gaze monitoring improves in normal development as children get older. The aim of Expt 1 was therefore to investigate performance on both the GMT and VPT in children with autism, Down syndrome and normally developing children.

## EXPERIMENT 1

### Method

*Participants*

In the autism group there were 12 children (mean age 11:8 years, range 5:7–17:5) from a special school for autism and communication disorders in the south-east of England (Surrey). All had a score on the Childhood Autism Rating Scale (CARS; Schopler, Reichler & Renner, 1988) of above 30 (criterial for autism), ranging from 30–55. In addition, they all met Rutter's (1978) diagnostic criteria for autism. The Down syndrome group comprised 11 children from a special school for children with developmental delay in a neighbouring county (Kent) (mean age 7:7 years, range 4:6–12:3). The clinically normal group of 12 children were from a primary school in Kent (mean age 5:8 years, range 5:6–5:11).

All the children in the study had an expressive language level equal to or greater than two- to three-word utterances. All children also possessed the vocabulary skills to identify the six different toys used in the visual perspective taking task. As children had to comprehend and respond to a sentence (i.e. 'What am I looking at?'), the Test of Reception of Grammar (TROG; Bishop, 1983) was given. This test gives a receptive age equivalent score for grammar comprehension of 4 to 12 years. This test was given to the children with Down syndrome and autism. Normal chidren were not tested as it was assumed that verbal mental age (VMA) of the normal children would roughly match their chronological age (CA).

The autism and Down groups were subdivided into two chronological age subgroups. The six children with autism in the older age subgroup were aged 15:4–17:5 years. All had a verbal MA on the TROG of above 4 years. In the younger age group (CA 5:7–9:0 years), only one child had a verbal mental age above

4 (MA 7:0 years). The remaining five had an MA of less than 4 years, below the testable standard for the TROG. It was not possible to match the Down group exactly. The CA of the older Down group ranged from 9:2–12:3 years. Three had verbal MAs of 4:6 years. The other three passed either three or four blocks of the test but failed to reach the 4-year level (five blocks). The CA of the younger group ranged from 4:8–7:7 years. All were below the testable standard for the TROG.

**Table 1.** Chronological age (CA) and mental age (MA) of participants in Expt 1

| Group | Age | | CA | MA[a] |
|---|---|---|---|---|
| Normal | | *M* | 5:8 | — |
| | | SD | 0:2 | |
| | | Range | 5:6–5:11 | |
| Autism | Older | *M* | 16:5 | 5:4 |
| | | SD | 0:10 | 1:4 |
| | | Range | 15:4–17:5 | 4:3–8:0 |
| | Younger | *M* | 6:11 | Below testable age |
| | | SD | 1:6 | |
| | | Range | 5:7–9:0 | |
| Down syndrome | Older | *M* | 10:8 | See pp. 79–80 |
| | | SD | 1:6 | |
| | | Range | 9:2–12:3 | |
| | Younger | *M* | 5:6 | Below testable age |
| | | SD | 1:2 | |
| | | Range | 4:8–7:7 | |

[a] Test of Reception of Grammar (TROG).

### *Materials*

Materials for the GMT were based as far as possible on those described by Butterworth & Cochran (1980) and Butterworth & Jarret (1991). Two chairs were placed opposite each other, 50 cm apart, in the centre of a sparsely furnished school room. The room sizes were 380 × 412 cm, 410 × 326 cm and 240 × 184 cm respectively. Targets comprised two yellow stars (20 × 20 cm) attached to each wall to the right and left of the dyad, at the experimenter's eye level. A door or exit behind the child's chair provided the rear target. A video camera was positioned behind the experimenter to record both her head movements and the child's head and eye movements. For the VPT, Baron-Cohen's (1989) task was used. The layout and positioning of the toy objects were exactly as described by Baron-Cohen (1989). A high shelf was erected behind the child and two tables placed beside each child. Six toys were used (teddy, clock, ball, doll, cup, car), three behind the child, one at each side, and one in front of the child on the floor. The experimenter checked before the task started that children were able to identify and name each toy correctly.

### *Design and procedure*

Three trials of the GMT were given in one testing session. The six trials of the VPT were also conducted in one testing session a day later.

*Gaze monitoring task (GMT).* The experimenter sat opposite the child, and first engaged him or her in interaction by singing or conversation. This was to ensure that she had the child's full attention and eye-contact. At the point when she had eye contact, she then immediately looked at a target either to the left or the right (at 90 degrees from her midline), or behind the child, fixating the target for six seconds. During these six seconds, she maintained a facial expression as if to indicate that she had seen something of interest. The experimenter re-established eye-contact again before starting the next trial. Three separate locations were used, left, right and behind. Each child received the left/right trials in random order and the behind trial last. The behind trial was given last in view of its potential difficulty for children as noted by previous research with infants.

*Visual perspective taking task (VPT).* Baron-Cohen's (1989) procedure was followed. The experimenter sat opposite the child. Then for each trial, she kept her head still, facing straight ahead, closed her eyes and moved them under closed lids to face one of the toys. She then opened her eyes and while focusing on a toy, asked the child 'What am I looking at?'. The experimenter allowed the child time to turn and look at the toy before making its response. In response to this question, children followed the experimenter's line of sight and verbally labelled (rather than pointed to) the object. If the child still did not respond, one prompt was used: 'Which toy am I looking at?'. The order in which the toys were looked at by the experimenter was randomized.

### Scoring

The GMT was scored from videotape after the experiment by panels of judges (of four or more people) all of whom were blind to the hypothesis of the study. Scorers were initially told that an adult on the videotape would look to the left, right and behind and asked to score the child according to whether or not he or she looked in the same direction as the experimenter. An instruction was given to indicate the start of each trial. Each judge rated the videotapes indpendently without consultation with other members of the panel. Children were scored as monitoring gaze on each trial if 90 per cent judges or more rated them as following gaze for that trial. Children were subsequently scored as 'passers' on the gaze monitoring task if they monitored gaze (as agreed by over 90 per cent judges) on at least two out of three trials. This scoring criterion is consistent with the level set by Scaife & Bruner (1975; 1 or more out of 2), Morisette, Ricard & Decarie (1995; 2 or more out of 4) and Moore & Corkum (1994; 2 or more out of 4).

The VPT was scored by the experimenter who recorded the child's answer to each question during the experiment. In order to equate the scoring of this test to the scoring of the GMT, participants were scored as passing the VPT if they gave correct answers on at least four out of six trials.

## Results

The results for both the GMT and VPT are summarized in Table 2.

**Table 2.** Number of participants passing the GMT and the VPT

| | GMT | | VPT | |
|---|---|---|---|---|
| | Pass | Fail | Pass | Fail |
| Autism | 2 | 10 | 8 | 4 |
| Down | 8 | 3 | 9 | 2 |
| Normal | 9 | 3 | 12 | 0 |

*Gaze monitoring task.* Seventy-five per cent of the normal children and 72.7 per cent of the children with Down syndrome spontaneously monitored gaze by looking in the same direction as the experimenter, on at least two out of three trials. In contrast, only 16.6 per cent of the children with autism passed the gaze monitoring task. This difference was highly significantly (autism × down, $p$ = .0095;

autism × normal, $p = .006$, both Fisher's Exact probability tests). Examples of responses by children with autism and Down syndrome are illustrated in Fig. 1.

**Down syndrome**

1s after experimenter fixates target to left—subject follows gaze direction.

4s after experimenter fixates target—subejct checks if experimenter is still looking at target.

**Autism**

1s after experimenter fixates target to right —subject looks at experimenter's profile.

4s after experimenter fixates target—subject attempts to get experimenter's attention.

**Figure 1.** Response to gaze monitoring task by child with Down syndrome and child with autism.

The poor gaze monitoring performance shown by children with autism was not due to a pattern of responding which involved monitoring gaze on the first occasion only and ceasing this behaviour on subsequent trials. Only two children with autism, one with Down syndrome and one normal child showed this pattern. Further analysis of the consistency of responses for children who passed the GMT (i.e. at least two correct trials) showed that very few children (one autism, four Down, three normal) monitored gaze consistently on every single trial. Analysis of the location of children's responses (i.e. left, right and behind) showed that, of the participants who passed the GMT, seven Down participants and one autistic participant monitored not only to the side (i.e. within their visual field) but also behind them. Surprisingly, however, less than half of the normal children who passed this task (four out of nine) monitored gaze behind them.

*Visual perspective taking task.* There was no significant group difference for this task. Of the children with autism, 66.6 per cent, of the children with Down syndrome, 82 per cent, and of the normal children, 100 per cent passed this task by correctly identifying the object being looked at by the experimenter on at least four out of six trials ($\chi^2(2) = 4.60, p > .10$). Further analysis of the consistency and location of responses for children who passed the VPT (i.e. at least four correct trials) showed that five autistic, seven Down and 11 normal children all gave correct answers on every single trial. Three autistic and one normal child gave five out of six correct answers because they made an error when the experimenter was looking at a toy *behind* the child, and one Down child made an error both to the side and behind.

*Contingency between tasks.* Analysis of the contingency between GMT and VPT showed a significant group difference. Table 3 shows that the most common response for normal children (nine) and children with Down syndrome (eight) was to pass both tasks. In contrast, only two children with autism passed both tasks ($\chi^2(2) = 10.57, p < .01$) (rows 2, 3 and 4 of Table 3 collapsed to avoid small expected frequencies). Unlike the normal and Down children, the most common response for children with autism was to pass the VPT but fail the GMT. Six children with autism produced this response pattern in comparison with not one single child who gave the opposite response of passing the GMT and failing the VPT (McNemar's test: $\chi^2(1) = 4.66, p < .02$). Unlike the autism group, there was no significant asynchrony between these two response patterns for the other two groups (Down, 1 vs. 0, McNemar's test $\chi^2(1) = 1, p > .50$; normal 3 vs. 0, McNemar's test $\chi^2(1) = 3, p > .10$).

*Age.* In the older age groups, performance on the VPT did not differ between Down and autism children. Five children with autism and six Down children passed the VPT. In contrast, the older age groups were very different in their performance on the GMT. Whilst every older Down child (six out of six) monitored gaze in the GMT, no child in the older autism group did so (zero out of six) (Fisher's Exact probability test, $p = .002$). In the younger age groups, performance did not differ between Down and autism participants on either task. Three of five Down and three of six autistic children passed the VPT whilst two of five Down and two of six autistic passed the GMT. Of the two autistic children who passed the GMT, however, one had a CARS score of 30, indicating a borderline case of autism.

**Table 3.** Contingency between performance on the GMT and the VPT, according to age

| | Autism | | | Down syndrome | | | Normal |
|---|---|---|---|---|---|---|---|
| Tasks | Young | Old | Total | Young | Old | Total | Total |
| Both correct | 2 | 0 | 2 | 2 | 6 | 8 | 9 |
| VPT only | 1 | 5 | 6 | 1 | 0 | 1 | 3 |
| Gaze only | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Neither | 3 | 1 | 4 | 2 | 0 | 2 | 0 |

## Discussion

This study shows a striking difference between children with autism and control children in the ability to use information about eyes. There were clear differences in the pattern of performance in the GMT and VPT. Taking the sample as whole, the majority of the normal children and those with Down syndrome passed both tasks, whereas most children with autism gave a different response pattern—passing the visual perspective taking task (VPT) but failing the gaze monitoring task (GMT).

One of the questions we were interested in was whether age or verbal ability would affect performance. The results of Expt 1 indicate that performance on the VPT does seem to be influenced by verbal mental age and the effect seems to be similar for both groups. Whilst all but one of the autism and Down participants with higher verbal MA passed the VPT task, half or less than half of autism and Down participants with lower MA did so. This supports Hobson's (1984) earlier finding that performance on visual perspective taking tasks is influenced by mental age. It also explains why fewer of our total autism sample (66.6 per cent) passed the VPT than in Baron-Cohen's (1989) study (92.5 per cent). Children in Baron-Cohen's study had a mean verbal MA of 5:5 years, closer to the mental age of our older MA group.

In contrast to the verbal age on the VPT, children with autism did not improve with verbal mental age when it came to the GMT. Even when children with autism have a higher CA and verbal MA, they do not monitor gaze in the GMT, despite their gaze monitoring ability shown in the VPT. Only two children from the entire sample with autism passed the GMT. Both of these were in the younger CA age group, but as mentioned, one of these children could be considered a borderline case for the diagnosis of autism, given his CARS score of 30. The lack of improvement with mental age for children with autism does not apply to other participant groups, however. Children with Down syndrome showed a different picture. For the GMT, every single participant in the older group monitored gaze compared with less than a half of those in the younger group.

We were also interested in other developmental effects in gaze monitoring. To our knowledge, this is the first time that the GMT has been used with normal children above 2 years old and, in the absence of any baseline studies, we were interested to discover whether older children would show greater consistency in their responses than infants. In addition, we did not know whether children with developmental delay would show the same development as normal infants, with the ability to monitor gaze *behind* presenting particular difficulties. The results for these two aspects were interesting. First, there was no evidence to show that normally developing children improve in their spontaneous gaze monitoring to the extent that they follow gaze on every occasion. Instead, the results for 5-year-olds look much like that for normal infants, with 75 per cent passing the gaze monitoring task according to standard criteria used in infancy studies. Nevertheless, this result merits replication with a larger age group of children in order to trace developments from 2 years to 5 years and from 5 years and above. Whilst it appears that older children are performing similarly to infants, other processes may be at work as children get older. For example, the automatic tendency to monitor gaze may become socially inhibited as children get older. Such social inhibition might not be a feature in the performance of older Down children as it is for older normally developing children. Whether or not normally developing children become more inhibited in their responses with age, it is not surprising that there is variation in the frequency with which gaze monitoring occurs for both infants and older children, given that this is a spontaneous behaviour. What is striking, however, is the relative frequency with which this behaviour occurs in normal and Down children when compared with children with autism.

Another developmental aspect of interest was the effect of location on children's responding. The results for the GMT provided no decisive evidence that the behind location presented special difficulty for the developmentally delayed autistic and Down children. In fact, it was normal children who seemed to have this difficulty. The reason for this is not clear. One possibility is the idea of social inhibition mentioned above. Whereas a child might glance surreptitiously to the left or right in response to the experimenter's shift in gaze, they might be inhibited from turning round in their seat to look behind them. These explanations need further investigation with other samples of children of different ages. As it stands, the data do not completely rule out the possibility of a developmental progression in developmentally delayed children, from *within* visual field to *outside* visual field (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991). Although this effect was not evident in autistic or Down children for the GMT, there appears to be some indication of it for the VPT. As mentioned, where errors were made on the VPT these errors tended to be on a behind trial. Further inspection of the data for both passers and failers of the VPT shows that 82.6 per cent of both autism and Down groups gave consistently correct responses to all three within visual field trials of the VPT compared with 52 per cent giving correct responses to the three behind trials. This difference is not noticeable for the normally developing 5-year-olds, most of whom gave three correct responses on both types of trials (100 per cent within versus 91.6 per cent behind). Further studies are needed in order to pin down this developmental effect in autistic and developmentally delayed children and explore why this might occur in the GMT but not the VPT.

To summarize, this experiment showed that children with autism can use geometric skill to compute what a person can see, but do not use this skill to spontaneously monitor the target of another's gaze. A critical finding is the contingency between the two gaze monitoring skills as tested in the GMT and VPT. Whilst both these skills were closely related for the majority of normally developing children and children with Down syndrome, the most common response for children with autism was to follow gaze when instructed, but not spontaneously. This result indicates that geometric and joint attention skills dissociate from each other, with geometric skills developing independently in children with autism. If this is the case, a further question is whether this skill is similar to that seen in normal children. In Expt 2 we tested whether children with autism could follow line of sight not only on the basis of gross cues such as relatively large head or eye movements, but also on the basis of much finer changes in the direction and angle of the eyes.

## EXPERIMENT 2

In this experiment we employed a new geometric task to test the psychophysics of eye direction detection, under two conditions: (1) in which the distance between objects is varied, and (2) in which head-direction and eye-direction are concordant or discordant. The aim was to determine if children with autism would be at the same developmental level on these fine discrimination tasks as other children matched for verbal mental age. This geometric task was devised by Perrett & Milders, initially to test normal adults and patients with prosopagnosia. Some patients with prosopagnosia do show gaze perception deficits (Campbell, Heywood, Cowey, Regard & Landis, 1990; Perrett, Mistlin, Chitty, Harries, Newcombe & de Haan, 1988), but face identification and skills underlying the analysis of gaze direction appear to be dissociable (Milders & Perrett, 1993).

## Method

### *Participants*

Details of the participants in this experiment are shown in Table 4. None had taken part in Expt 1. We tested three groups of 20 participants. The first group all had a diagnosis of autism, using established criteria (Rutter, 1978; American Psychiatric Association, 1987), and were attending special schools for autism. The second group all had a mental handicap and were attending special schools for pupils with learning disabilities. This group included children with both Down syndrome and mental handicap of unknown aetiology. The third group were normal 4-year-olds, all attending a nursery school. All of the schools were in the greater London area. The two clinical groups had a verbal mental age (MA) (as assessed using the TROG) above 4 years old. The group with mental handicap did not differ significantly on mean verbal MA from the group with autism.

**Table 4.** Mean CA and MA of participants in Expt 2

| | | CA | MA + |
|---|---|---|---|
| Normal | *M* | 4:3 | |
| | SD | 0:2 | |
| | Range | 4:0–4:8 | |
| Mental handicap | *M* | 6:2 | 4:9 |
| | SD | 0:6 | 0:6 |
| | Range | 5:0–7:6 | 4:0–6:0 |
| Autism | *M* | 13:5 | 4:9 |
| | SD | 3:3 | 0:5 |
| | Range | 8:0–18:2 | 4:0–5:8 |

### *Materials and procedure*

The full test devised by Perrett & Milders comprises 36 colour photos of a stimulus head looking at one of three coloured rods in turn. The participant is asked to identify which rod the person in the photo is looking at. In card number 36, the spacing between the three rods is quite wide and these spaces diminish progressively as one works through the sequence (see Fig. 2). In the version of the test given here, only pictures 36–19 were used, since our pilot studies revealed that, beyond this, participants in all three groups were at chance level.

Each child was tested individually in a quiet room at his or her school. The experimeter first asked the colour control questions: 'Can you show me the red/green/yellow rod?' After the child had answered the three colour control questions correctly, the experimenter continued: 'Now let's play a game. I am going to show you some photos of my friend Dave. He is looking at one of these three rods. Sometimes he is looking at the green one, sometimes at the red one, sometimes at the yellow one. Can you tell me which rod Dave is looking at, in the photo?' A colour name or touch response indicating one of the three rods was scored. The photographs were presented in a fixed order (starting with number 36 down to number 19), one by one. These were presented until the child had made six or more errors out of eight consecutive trials or until the child had reached card 19. Participants looked at the photographs from a distance of 30–40 cm. The rate of presentation was determined by the participant's responses.

The original set of photographs was prepared using a 35 mm camera with 90 mm lens. The rods were 45 cm high. In pictures 36–28, the rods were separated by 20 degrees. In pictures 27–19, the rods were separated by 10 degrees. The yellow rod was always 20 degrees to the right of the stimulus head while the red and green rods were always positioned at an angle respectively smaller and larger than 20 degrees. Degrees here are measured from the stimulus head. The stimulus head was 53 cm away from the rods and

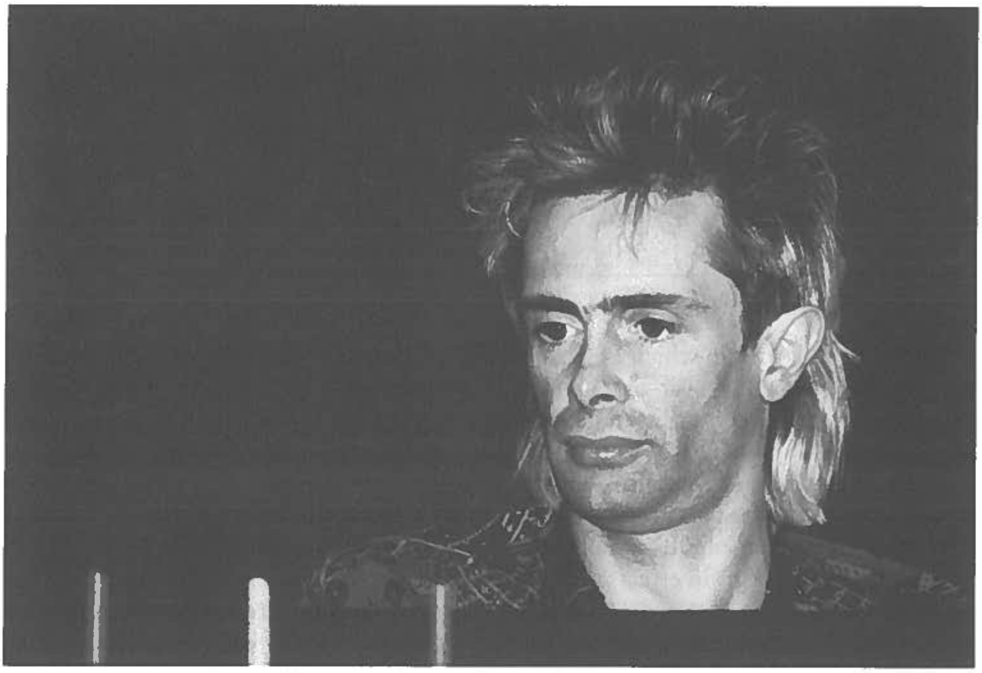

**Figure 2.** Examples of pictures used in Expt 2.

280 cm from the camera. In addition, both head orientation and eye direction were varied systematically, such that these were either 40 degrees, 30 degrees, 0 degrees or 20 degrees and either matched or mismatched. This meant that the stimulus head could be directed towards the green rod whilst the stimulus head was actually looking at the yellow rod. This ensured that participants could not rely solely on either head orientation or the position of the iris within the visible sclera as the sole cue to task solution. The colour of the peg looked at was also randomized so that three head orientations each with three possible eye orientations were tested in a block of nine pictures.

## Results and discussion

The performance of the three groups is shown in Table 5. None of the group differences was significant (autism × MH, $t(38) = 0.847$, $p = .4$; MH × normal, $t(38) = 0.92$, $p = .36$; autism × normal, $t(38) = 1.78$, $p = .08$), though there was a trend towards the children with autism being superior to the normal group. This lack of significant difference was also reflected in an analysis based on percentage of children passing the task given a criterion for passing of nine or more out of 18 (i.e. 45.5 per cent normal, 54.2 per cent MH, 62.8 per cent autism). A further analysis of percentage passing using a criterion comparable to Expt 1 (i.e. four or more correct of first six trials) also showed no significant difference between the three groups (45 per cent normal, 60 per cent MH, 70 per cent autism; $\chi^2(2) = 2.43$, $p > .30$).

**Table 5.** Mean number correct (maximum = 18) by each group

| | | | Percentage passing | |
|---|---|---|---|---|
| | | Mean score | (Pass >9/18) | (Pass >4/6) |
| Normal | *M* | 8.2 | 45.5 | 45 |
| | SD | 5.1 | | |
| Mental handicap | *M* | 9.8 | 54.2 | 60 |
| | SD | 5.6 | | |
| Autism | *M* | 11.3 | 62.8 | 70 |
| | SD | 6.0 | | |

This is the first time in which Perrett & Milders' task has been used with children. The finding that normal 4-year-old children's performance is worse than adults is an indicator that geometric ability must continue to develop beyond 4 years of age. This is consistent with Lord's (1974) study. Children with autism were within the expected range for their MA in this ability, and even showed a trend towards a slight superiority in relation to the other two groups in their ability to compute what a person was looking at. Given that in the mentally handicapped group, CA was significantly lower than in the group with autism, this in effect means that the group with autism had a lower IQ than the other two groups. It remains possible therefore that if the groups had been matched on IQ rather than MA, this trend towards an autism superiority on this task would have reached statistical significance. At the very least, this study shows that they can discriminate what a person is looking at when the object is separated by another by an angle of 10 degrees. Given the photograph size and viewing distance, the change in eye position would cause the contours of the iris to displace through an angle of only 3.5 minutes arc on the child's retina. This discrimination capacity is thus close to the Snellen acuity. It is interesting to note that many of the children with autism used a very concrete strategy of physically tracing a line with their index finger from the stimulus head's eyes to the rod, a strategy not seen in the other two groups.

## GENERAL DISCUSSION

Taken together, these experiments suggest that children with autism approach eye-direction detection solely as a geometric problem. Our results extend earlier studies of visual perspective-taking (Baron-Cohen 1989, 1991; Hobson, 1984; Tan & Harris, 1991), showing that children with autism can make fine discrimination of eye direction well within the ability expected for normal children of the same MA. By the MA of 4 years they can accurately report what someone is looking at, whether this object is above them, to the side of them, below them, close to another object and even when the person's head is in one direction and their eyes in another. Yet unlike infants and children with Down syndrome, they do not spontaneously use this skill to monitor the target of another person's gaze when that person turns to look at an object.

This result supports and extends other findings showing that children with autism have a deficit in joint attention (e.g. Baron-Cohen, 1989; Curcio, 1978; Landry & Loveland, 1988; Loveland & Landry, 1986; Mundy, Sigman & Kasari, 1990; Mundy, Sigman, Ungerer & Sherman, 1986). The result of Expt 1 suggests that joint visual attention does not appear to develop with either increasing chronological or mental age in children with autism. Thus, even those with verbal MAs up to an equivalent of 8 years of age did not spontaneously monitor gaze. In contrast, this ability does appear to develop in line with mental age for Down syndrome children.

On the face of it, this result seems to contradict the findings of some other studies such as Landry & Loveland (1988), Mundy *et al.* (1990) and Stone & Caro-Martinez (1990), who found that joint attention ability in autism is correlated with verbal ability. However, apart from the fact that these studies used participants with much lower verbal ability and CA level than in this study, there seems to be another difference between the findings. It appears that the critical joint attention behaviours for predicting language development in those studies were those concerned with pointing and showing. These *attention directing* gestures (what Mundy *et al.*, 1990, call 'gestural attention skills') contrast to the joint *visual attention* skills examined here which involve *responses* to another's head and eye movements. The difference in the findings between this and other studies deserves further investigation, however, and we are currently involved in a larger study using different measures of both expressive and receptive language ability and different types of joint attention skills.

Overall, the results for Expts 1 and 2 raise an important question about the similarity of normal and abnormal developmental processes. In normal development, gaze monitoring in the first 18 months of life is proposed to proceed through several separate stages. Butterworth & Jarrett (1991) argue that three successive mechanisms are at work. The first, an ecological mechanism, depends on two aspects: (*a*) the attention capturing properties of the environment and (*b*) the change in mother's direction of gaze. The second mechanism, the geometric mechanism, depends on the ability to extrapolate invisible lines from head or eyes to object. Finally, the representational mechanism involves the ability to extend joint attention to a space not only within the child's visual field but *outside* it, to a represented space.

Butterworth and colleagues propose that in normal development infants progress through these 'stages' sequentially, with the ecological mechanism appearing at approximately 6 months, the geometric mechanism appearing at about 12 months and the representational mechanism at about 12–18 months. The results for both Expts 1 and 2 indicate a different pattern of development for children with autism. That is, while the geometric mechanism is intact, the ecological mechanism is in some way faulty. There is also evidence suggesting a delay or deficit in the appearance of the 'representational' mechanism. Although a failure to follow gaze behind the child was not found in the GMT, it should be noted that in this task the experimenter moved both head and eyes together. Even the behind trial might have been indicated by some shift in the experimenter's head movement. Futher studies are needed in which the procedures for the GMT and VPT are identical since other studies show that infants progress from a point where they rely on only head orientation to one in which they also rely on eye orientation also (Corkum & Moore, 1995). In the VPT, however, the shift in gaze was controlled so that it took place when the experimenter's head was still. In this task there was some indication that behind trials were more difficult that within trials for both children with autism and Down syndrome but not for normal 5-year-olds. This effect was not found in Baron-Cohen's (1989) study, possibly because of a ceiling efffect due to the sampling of high MA children. Further research, however, may be able to pin down developmental changes in this ability in children with different types of developmental disability.

If, in Butterworth's terms, children with autism lack a basic ecological mechanism for spontaneous gaze following, which part of this mechanism is damaged? Do children lack the capacity to be captured by an attention grabbing feature of the environment, or are they unable to understand the relation between the direction of the experimenter's head turn and the direction in which to look?

The first possibility, that children with autism fail to be captured by an interesting stimulus outside of the central vision, might be explained by research showing that people with autism have difficulties in shifting attention both between modalities (Courchesne, Townsend, Akshoomoff, Saitoh, Yeung-Courchesne, Lincoln, James, Haas, Schreibman & Lau (in press) and within modalities (Casey, Gordon, Mannheim & Rumsey, 1993; Wainwright-Sharp & Bryson, 1993). An explanation in these terms would state, not that children fail to be captured by stimuli, but that once their attention is captured (e.g. by a central stimulus such as someone talking), they have trouble disengaging and shifting their attention to another location. In Courchesne's view the attentional deficits in autism are the result of cerebellar pathology. A related but different analysis has been proposed by Russell and colleagues (Hughes & Russell, 1993; Russell, Mauthner, Sharpe & Tidswell, 1991) and by Ozonoff, Pennington & Rogers (1991). Evidence for difficulty in disengaging from a stimulus and difficulty shifting cognitive set has been explained as evidence for an executive dysfunction, indicting a frontal lobe impairment. A similar difficulty of inhibiting attention to a central stimulus has also been noted in very young normal infants and linked to oculomotor maturation, sensory processing and a possible impairment in parietal and frontal cortical regions (Hood, 1995). Further research into the attentional and motor responses of both normally developing and autistic children may help to integrate these views and to pin down the link between attention and social responsiveness.

The second possibility, that children with autism are unable to understand the relation between the direction of the experimenter's head and the direction in which to look, raises a question about what the child understands about the signal of another person's head movement as an indicator of something of interest. At one level of analysis, the child may fail to read gaze or head movement as an index of the person's state of attention or interest. He or she therefore fails to detect the significance of the other person's action and fails to respond to it. This explanation fits with the claim that autism is due to a cognitive deficit in the development of a theory of mind (Baron-Cohen, Leslie & Frith, 1985; Leslie and Roth, 1993; Perner, Frith, Leslie & Leekam, 1989). Support for this view may be found in a recent study by Baron-Cohen, Campbell, Karmiloff-Smith, Grant & Walker (1995). In this study, children with autism were shown a cartoon character whose gaze was randomly directed to one of four objects and asked what that person wants, or is going to take. These children failed to use eye direction to infer the character's mental states of desire, goal or refer. Children with autism may therefore fail to monitor gaze spontaneously because they fail to identify that both they and another person are attending to the same thing (Baron-Cohen, 1994). This supports the idea that joint attention may be a precursor to the development of a theory of mind (Baron-Cohen, 1994; Baron-Cohen & Cross, 1992; Bretherton, McNew & Beeghly-Smith, 1981).

At another level of analysis, the gaze monitoring task may not involve the child representing that the adult is looking at something (Moore & Corkum, 1994). Instead, in normal development, the child may learn a simple contingency between a mother's head turn and a rewarding event. As Moore & Corkum (1994) point out, 'initially the infant interprets the other's head turn as a signal to produce a response with the expectation that the response will lead to an interesting sight . . . not that there will be an interesting sight in the place which is a common focus of attention' (p. 355). Using a conditioned head turn procedure with normal infants, Corkum & Moore (1995) showed that the gaze monitoring response can be acquired through conditioning in infants who initially fail to monitor gaze spontaneously. We are currently engaged in investigating whether children with autism can also learn to acquire this spontaneous response through the same procedure.

Both levels of analysis may be operating in the child's understanding of the link between another's head and eye direction and where to look. Children may be born with a basic innate mechanism for detecting orientation of eyes and head movements and cognitive representations at increasing levels of complexity may then build upon this mechanism in normal development (Baron-Cohen, 1994) so that with age children come to appreciate another's attention. It is highly likely that social experience will play an important part in this development. The specific way in which social experience may facilitate and/or respond to development of such cognitive representations is an important area for future investigation.

To summarize, the results of our experiments indicate that the geometric component of gaze direction detection is intact in autism, while the ecological component is faulty. This problem may be due to several different underlying factors. For example, children with autism may fail to be captured by attention grabbing events in the environment (e.g. an attention shifting deficit), they may have difficulty in understanding the link between other's head direction and an interesting event or object, or they may be unable to represent that self and other are attending to the same thing. Testing between these options is an important next step.

A final interpretation of our results should be considered that is not confined to the problem of joint attention and social understanding in autism. Perhaps children with autism have a general problem with generating spontaneous responses. Other studies have found similar differences between spontaneous and elicited tasks for pretend play (Lewis & Boucher, 1988) and for imitation (Brown, 1995). Why should children with autism have difficulty with spontaneity in these tasks? One possibility is that this more general problem might be due to a motivational impairment. The idea would be that children with autism could do these tasks when instructed to, but lack the necessary incentive to so so spontaneously. Inspection of the videotapes from the gaze monitoring task in Expt 1, however, shows that the children did seem motivated to respond to the experimenter when she broke the interaction. A number of children made efforts to turn the experimenter's head back towards them when she turned to look at the target. These efforts included leaning forward towards the experimenter to look at her face (see Fig. 1), putting a hand out towards her, shouting to get her attention, laughing, talking avidly to her and asking her questions which were repeated when she did not respond. Further empirical work is needed to test whether children were sensitive to the break in interaction because they wanted to persevere with what they were doing (e.g. talking about something of interest to them) or because they wanted to regain mutual gaze and interaction with the experimenter. This could be tested by studying differences in the child's reaction to a break in interaction when either the experimenter or the child is talking.

Whilst cognitive and motivational explanations have each been considered, we should not rule out the possibility of an affective impairment. Hobson (1993), for instance, argues that in autism the difficulty lies with an inability to perceive directly and experience the affective meaning of another person's attitude. This is connected to the child's own ability to respond to that person's attitude by adopting the corresponding action or attitude themselves. Mundy *et al.* (1990) also propose an affective explanation. Their view is that a disturbance in arousal self-regulation (Dawson & Lewy, 1989) leads to atypical affective experiences and difficulty in recognizing the social value of affect. These theories indicate that what is primary in infant development is the predisposition to react preferentially to human stimuli. Recent work also stresses the importance of imitation (Meltzoff & Gopnik, 1993; Rogers & Pennington, 1991), and the developing ability to coordinate self with other.

Cognitive, motivational, social and affective factors are not mutually exclusive and it is unlikely that each of the interpretations above provide separate and alternative explanations for the development of joint attention. The important question is how these factors interact and influence each other in development. Future attempts to pin down what is intact and what is impaired in the joint attention of children with autism will help to provide a better understanding of one of the earliest indicators of this disorder, whilst at the same time providing an important focus for identifying basic developmental mechanisms.

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